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A comprehensive literature review of bio-fuel performance in internal combustion engine and relevant costs involvement

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ABSTRACT

Bio-fuel has come under consideration due to the effect of fossil oil crisis. Bio-fuels are acting as a renewable replacement of petroleum fuels due to some environmental and economic benefits. Bio-fuel can be produced from different kinds of raw materials. Researchers have seen that absolute utilization of bio-fuel is not appreciable as it will affect the food chain but the blend of bio-fuel with conventional fuel could precisely reduce its use and become beneficial to green house effect. It has been inferred that in the hot and cold environment bio-fuel is not fully convenient to replace fossil fuel. In the controlled environment with modified combustion equipment, biodiesel can be used as an alternate fuel. Research results reveal that bio-fuel has lower heating value in comparison to diesel fuel so it is consumed more in fuel-break mean effective power ratio and emits more NO_x in comparison to the diesel fuel. Thus there remains a compromise between GHG emission and saving of fossil fuel energy by introducing bio-fuel either totally or as a blending component of engine fuel. Finally, bio-fuel could be considered as a replenishable energy source which might pave the future pathway management and planning of energy.

Contents

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1. Introduction

Oil crisis in 1970 had influenced many countries to consider alternative fuels for replacement of fossil fuel [1]. So, blend of bio-fuel with conventional fuel could precisely reduce its use and become beneficial to green house effect. In the hot and cold environment bio-fuel is not fully convenient to replace the fossil fuel. However, in the controlled environment with modified combustion equipment bio-fuel can be used as an alternate fuel. Bio-fuel having lower heating value is consumed more in comparison to diesel fuel. It also generates more NO_x emission, which has an adverse effect on the environment. Raw material source of bio-fuel limits the food growing ground, which is ultimately becoming a great concern.

Bio-based systems develop other doable ecological drawbacks. Biomass from agricultural resources is comparatively land intensive, and they are engaged with water resources pollution risk from pesticides and fertilizers, which are needed to add to the land to enhance plant growth. Many scientific studies have observed this conundrum and also have tried to investigate bio-ethanol programs in the shot to explain their sustainability in the environmental. They have also discovered bio-based fuels to provide sustainable objective for environmental transportation. Some numerous studies have shown experiments with summarized results. One study dedicated to ethanol alone which provides typically undesirable tips [2,3]; the alternative review examined the bio-fuels of many typical types have presented some favorable results for ethanol, however they are cautioned regarding many environmental impacts [4]. It has enlisted varieties of studies which searched particularly the corn-to-ethanol route in the United States. It was terribly important for its environmental sustainability [3,5–7].

However, the question of problem of sustainability is sophisticated, which encompasses environmental and human health along with societal desires. This is obvious that the attempts to obtain distinguish solutions need to widen scope to prevent changing issues from one spot to a different one [8]. Many researchers have mentioned that these systems of liquid bio-fuel production, both projected and current, may a figure out an eco-friendly system from the currently used processes [3].

Bio-fuel is actually known as a renewable energy, which is produced from alternative renewable energy materials. The most prevalent bio-fuels, like biodiesel from vegetable seeds and ethanol from wheat, corn sugar beet, are produced from food plants, which require the rich agricultural land for growth [9–11].

Currently critical issues are dealt with global food offer. Fuel vs. Food could be a problem with regards to the danger of diverting crops farmland for producing liquid bio-fuels which is detrimental to the worldwide food supply. There are differences concerning how important this could be and what the impact is, what it inflicting and what will be done concerning it. Recently, the increase in world oil costs generated a pointy improvement in the global bio-fuels production. Some products like sugar-cane, vegetable oil and corn are going to be used either as feed, food, or even create bio-fuels. Seed oils can be sustainable along with all of unlimited chances to obtain energy having fuel energy content near to the diesel fuel. In addition, intensive usage of vegetable oils could potentially result in different important issues like food shortage in developing countries. Agricultural education and forestry are fashionable technology which leads the handling of global food supply issues [9,12,13].

Energy costs influence clients decision and behavior and might have influenced on economic development. The relevant taxes of energy cost need to be definitely recognized from prices, contract markets, spot markets and averaged prices from sample prices. Biomass fuel includes the main exploited global renewable energy. High capability, Low priced methods for the process of biomass into liquid bio-fuels conversion are crucial for minimizing reliance on petroleum sources, increasing the employment of neutralizing carbon techniques, and improving rural profits [14,15]. Grain-based vegetable-oil and ethanol are mostly dependant on biodiesel and used recently with an agony from the competition while using food grains [9].

The goal is always to supply cheap biomass to a stream which is accustomed to selection of chemicals, fuels and alternative materials which might be cost competitive to the regular products. The definition of liquid bio-fuel is noted as biomass-to-liquid fuel. BTLF can supply completely different renewable sources to petroleum; on the other hand it still incorporates a low quantity of petroleum in the blend. The main distinction between petroleum and bio-fuels feedstocks is content of oxygen [16,17].

Two global liquid transportations of bio-fuels can be replaced by diesel and gasoline fuel; these include biodiesel and bio-ethanol, correspondingly. The biodiesel can be used as a replacement for petroleum diesel whereas bio-ethanol is utilized as a replacement of gasoline [18–20].

Biodiesel means any kind of equivalence between diesel and bio-fuel typically derived from animal fats or seed oils. Specifically, it can be employed as fuel of some engines, or mixed with petroleum in diesel engines with no or a few modifications. Biodiesel has developed into a wide range of engagement for the environmental advantages [21,22]. The biodiesel expense is usually the main obstacle for commercial trade. Cooking oils are used as a staple, the possibility of a nonstop transesterification method and the best glycerol quality recovery as a production of primary choices of biodiesel are considered for the price reduction of biodiesel [9,11,23,24].

The thermochemical conversion techniques of biomass are endothermic in nature and the heat dissipated is similar to different renewable energy sources like solar energy. The fuel made ideally represents the whole of energy kept during the entire photosynthesis and also the direct thermal assortment [9,25]. However, if additional energy is provided from other renewable resources like wind and solar, then the additional biomass carbon could to be changed to the

Nomenclature

AFR	air–fuel ratio
ASTM	American Society for Testing and Materials
BSFC	brake specific fuel consumption
BTLF	biomass-to-liquid fuel
Btu	British thermal units
CGF	United States corn gluten feed
CI	compression-ignition
DI	direct fuel injection
EIA	energy information administration
ETBE	ethyl *tert*-butyl ether
GHG	green house gas
GJ	giga joule
Ha	hectare
HC	hydrocarbon
HHV	higher heating value
IDI	indirect fuel injection
KW	kilowatt
L	liter
LHV	lower heating value
MJ	mega joules
MTBE	methyl *tert*-butyl ether
NA	naturally aspirated
N m	Newton meter
PEC	pure energy corporation
PM	particulate matter
PROALCOOL	National Alcohol Program
RFG	reformulated federal gasoline
rpm	revolutions per minute
SI	spark-ignition
TU	turbocharged
USDA	United States Department of Agriculture
VOCs	volatile organic compounds
VOME	vegetable oil methyl ester
WC	water-cooled
γ	air–fuel ratio

liquid fuel [26,27]. Solar energy can possibly supply a few percentages of the thermal energy of bio-fuel plants. The use of direct focused radiation in biomass reactors has been considered and analyzed to meet challenges. Solar radiation energy can be stored as energy and utilized for the temperature levels required in processing of biomass. An operating fluid might transfer heat to the bio-fuel under process if required [25,28].

2. History

Rudolph Diesel was educated at the predecessor school to the Technical University of Munich, Germany. In 1878, he was introduced to the work of Sadi Carnot, who theorized that an engine could achieve much higher efficiency than the steam engines of that day. Carnot envisioned a cycle in which a gas is compressed, heated, allowed to expand, and then cooled. After the gas is cooled, the cycle begins anew. Mechanical energy is used to compress the gas and thermal energy to heat it. In turn, expansion of the gas yields mechanical energy, and its cooling yields thermal energy. The net result is conversion of thermal energy to mechanical energy [29,30].

Diesel sought to apply Carnot's theory to the internal combustion engine. The efficiency of the Carnot cycle increases with the compression ratio – the ratio of gas volume at full expansion to its volume at full compression. Nicklaus Otto invented an internal combustion engine in 1876 that was the predecessor to the modern gasoline engine. Otto's engine mixed fuel and air before their introduction to the cylinder, and a flame or spark was used to ignite the fuel–air mixture at the appropriate time. However, air gets hotter as it is compressed, and if the compression ratio is too high, the heat of compression will ignite the fuel prematurely. The low compression ratios needed to prevent premature ignition of the fuel–air mixture, which limits the efficiency of the Otto engine [29,30].

Rudolph Diesel wanted to build an engine with the highest possible compression ratio. He introduced fuel only when combustion was desired and allowed the fuel to ignite on its own in the hot compressed air. Diesel's engine achieved efficiency higher than that of the Otto engine and much higher than that of the steam engine. Today, diesel engines are classified as “compression-ignition” engines, and Otto engines are classified as “spark ignition” engines [29,30].

Diesel's motivation was not only to improve efficiency but also to bring the benefits of powered machinery to smaller companies. Steam engines were so large that only the biggest firms could afford them, and Diesel wanted to enable smaller firms to compete against larger, steam-powered firms. He used peanut oil as the fuel for his demonstration in engines at the 1900 World's Fair and thought that oils from locally grown crops would be used to power his engines [29,30].

The early 20th century saw the introduction of gasoline powered automobiles. Oil companies were obliged to refine so much crude oil to supply gasoline, which was left with a surplus of distillate. Those could be an excellent fuel for diesel engines and of less expensive than vegetable oils. On the other hand, resource depletion has always been a concern with regard to petroleum. The agricultural products are replenishable and the farmers have always sought new markets for their products. Consequently, work has continued on the use of vegetable oils as fuel [29,30].

Early durability tests indicated that engines would fail prematurely when operating on fuel blends containing vegetable oil. Vegetable engine burning oil had been transesterified with alcohols, which exhibited no such problems and even performed better by some measures than engines using petroleum diesel. The formulation of biodiesel has come out of the early experiments [29,30].

Oil crisis in 1970 had influenced many countries to consider alternative flues as replacement of fossil fuel. The National Alcohol Program (PROALCOOL) in Brazil was accomplished by using product stimulation, distribution and also by use of ethanol fuel from sugar-cane [1]. To aid this program, the car manufacturing industry designed specific engines for running with the ethanol fuel is co-operation to the program. In 1986, this program established a landmark, when ethanol-fueled automobiles reached 96% of the market shares. In 1989, ethanol vehicles and flexible-fuel were no more interesting due to enhancement of ethanol fuel cost, which was ultimately failed to provide the advantages to the consumers [1].

Brazil in 1990 experienced increase of vehicle import due to the lower import tax. The modern production strategy encourages the local automotive enterprise to involve in continuous improvement and produce new items. Government encouraged manufacturer of small engines powered by cheap fuel turned Brazil into one of the largest leadership of automobile manufacturers. Recently, continuous analysis has developed the flexible fuel engines, which might run with any concentration of gasoline and ethanol blend.

Automobiles, which can run with the variable fuel engines those, attract many customers due to the possible ways to make a choice from gasoline and ethanol in accordance to the price and availability [1,31].

The interest has introduced escalation of research on renewable fuel in the crisis of depletion to fossil fuel and enhancement of global warming and climate change. The global increase of petroleum value has additionally raised the interest of studies on alternative fuels and preparation for it. Research on waste cooking oil, raw vegetable oil, biodiesel, ethanol and methanol is conducted on the use of them as renewable fuels. The first three of them could be used for diesel engines [32–38] and the rests are suitable for regular use as fuel for petrol engines [39–42]. Ethanol can be extracted from several types of raw materials like maize, corn, sugar-cane, cassava, sugar beets, etc. [43,44]. In Brazil since 1975, ethanol has been mixed with petrol as alternative elements to reduce fossil fuel consumption [45–47]. However, ethanol has not been commercially used for diesel engines. Many investigations have been done on the possibility of using ethanol as a diesel engine fuel. However, the limitations of using the appliances with ethanol fuel having special properties have not been nullified [48–50]. Ethanol has lower viscosity and density in comparison to diesel oil. These characters are challenging to blend with diesel oil [50].

More researches are required to obtain the method of mixing ethanol and diesel fuel and the suitability of using as fuel in present diesel engines. The goal of this analysis is to justify further research on the solubility of diesel in ethanol, blending of the ethanol and diesel fuel with the additive of normal butanol (n-butanol) and also study the emissions and performance of diesel engine operated by these blends and the pure diesel oil, respectively [51].

3. Bio-fuel production and costs

3.1. Biodiesel production and costs

Bio-diesels are often manufactured by different processes. Fats and vegetable oils could be transformed into fatty acids and they are subsequently converted to esters. Fats or oils can also be changed into ethyl esters or methyl directly, employing an acid or base to accelerate (catalyze) the transesterification reaction. As the catalytic is fast and thorough, a base catalyzation is preferred. Furthermore, it happens at lower pressure and temperature than that of different processes, contributing to reduced operating and capital losses for the biodiesel plant [30].

The expense of making seed oil that produces biodiesel is obtained at the expense of the fossil oil and cooking oil [52–54]. The most prevalent means of manufacturing biodiesel is from vegetable oil or animal fat with methanol and in presence of sodium hydroxide (basically, called lye or caustic soda). This response could be a transesterification of base-catalyzed, which produces methyl esters and glycerin. If ethanol is substituted for ethyl esters, methanol and glycerin are produced, as methanol is more cost-effective than ethanol, so it is preferred [30].

The Energy information Administration (EIA) works on the cost estimation of model feedstock impacts on the capital, operating and costs production. The feedstock expense of the grease or oil is the largest single element of biodiesel production costs. Yellow grease costs are lower than soyabean oil, however soyabean oil is prescribed, and it has used other than fuel like yellow grease, which is utilized as an animal feed additive and for producing detergents and soaps. The most popular yellow grease production in the United States was 2.633 billion pounds, which had generated 344 million gallons (22,440 barrels per day) of biodiesel from 1993 to 1998. EIA imposed usage limit of production of biodiesel from yellow grease to 100 million gallons annually (6523 barrels daily) [30].

The predictions of EIA on soyabean oil costs provide an assumed amount of oil employed for production of biodiesel in every prediction year [30]. Table 1 is showing the biodiesel production from soyabean.

The usage of energy for biodiesel production process, for each gallon is 38,300 British thermal units (Btu) and 0.083 kilowatt hours of electricity from natural gas. EIA refers the energy prices estimation (in 2002) as 18 cents per gallon in 2004 and 16 cents per gallon in 2005 and 2006. Modern biodiesel price estimation is $1.04 per annual gallon. EIA considers that the biodiesel plant will generate annual return of 10% over 15 years. The hypothetical income stream treating as an annuity over the 15 years, the capital expense estimation is $1.36 million annually, or 13.6 cents per gallon (2002 cents) at full output [30].

The National Biodiesel Board states that bio-diesels are plants dedicating an overall capacity of 60–80 million gallons annually (3414–5219 barrels daily). Additionally, the capability of 200 million gallons (13,046 barrels daily) can be obtained by producing from oleochemical, such as done by Proctor and Gamble. Biodiesel manufacturers can produce around 80 million gallons annually with a value just sufficient to cover variable prices. The ability inside the oleochemical industry is not going to return on-stream unless the expense of biodiesel is sufficiently high to attract methyl esters out of different uses. An evaluation of diesel fuel production price as sorted against feedstock is provided in Table 2 [30].

Biodiesel industry is currently holding excess production capacity. Petroleum refiner uses over 90% of their capability, and extra capital assets are required to stay up with improving capacity and specification of products. Soyabean is basically no sulfur oil biodiesel. The additional value of comparison between biodiesel cost, excluding capital, and the petroleum diesel costs, including capital [30] is presented in Table 2.

3.2. Bio-ethanol production and costs

A large scale of Ethanol is produced in Brazil, the United States, some European countries, and also a few Asian countries. It can be

Table 1
Use of soyabean oil for biodiesel production (dollars/gallon) [33].

Marketing year	50 million gallons of soyabean oil used for biodiesel production	200 million gallons of soyabean oil used for biodiesel production
2004/2005	1.95	2.22
2005/2006	1.91	2.17
2006/2007	1.87	2.15
2007/2008	1.84	2.12
2008/2009	1.86	2.20
2009/2010	1.89	2.25
2010/2011	1.94	2.35
2011/2012	1.99	2.41
2012/2013	2.06	2.47

Table 2
Projected production cost for diesel fuel from feedback [1].

Marketing year	Soyabean oil	Yellow grease	Petroleum
2004/2005	2.54	1.41	0.67
2005/2006	2.49	1.39	0.78
2006/2007	2.47	1.38	0.77
2007/2008	2.44	1.37	0.78
2008/2009	2.52	1.40	0.78
2009/2010	2.57	1.42	0.75
2010/2011	2.67	1.47	0.76
2011/2012	2.73	1.51	0.76
2012/2013	2.80	1.55	0.75

Table 3
Estimated bio-ethanol price compared to the oil price (bio-fuels exclusive of taxes), (US cents/liter) [9].

Bio-fuel	2006	Long term about 2030
Corresponding pre-tax price petroleum products	35–60	
Bio-ethanol from sugar-cane	25–50	25–35
Bio-ethanol from corn	60–80	35–55
Bio-ethanol from beet	60–80	40–60
Bio-ethanol from wheat	70–95	45–65
Bio-ethanol from lignocelluloses	80–110	25–65
Bio-ethanol from animal fats	40–55	40–50
Bio-ethanol from vegetable oil	70–110	40–75
Fischer-Tropsch synthesis liquids	90–110	70–85

prepared as one of the renewable dominating bio-fuels in the transportation systems within the approaching few years. Ethanol can be used as neat alcohol in specific engines or blended with petrol to approach higher heating value and the higher octane number. Additionally, it becomes a great fuel for future advanced flexi-fuel hybrid vehicles. Recently, ethanol fuel market is constructed from starch (United States) or sugar (Brazil) at competitive prices [55]. Table 3 shows estimated bio-fuels price [56].

There are several factors controlled by costumers which have influence on fuel economy. To achieve the best fuel consumption, the vehicle must be properly turned to meet the appropriate emissions requirement. Normal maintenance things, like keeping clean air filters, etc. can offer noticeable effects on fuel consumption. Factors that result in excess fuel delivery to the engine can lead to the reduced fuel consumption by 20% or more in the same vehicle under correctly tuned [57]. Alternative factors on which the consumer has control include:

1. Maintaining tire pressure will provide fuel economy.
2. Reducing aerodynamic drag, like the usage of cargo or cargo racks in the vehicle or driving with closed windows.
3. Carrying further and unnecessary weight in the vehicle like tool boxes, etc.
4. Aggressive driving, like quick acceleration and deceleration by using excess fuel.
5. Usage of air conditioning [57].

However, this staple base is additionally needed to be employed for human needs or animal feed, are not enough to satisfy the increasing requirement of ethanol fuel. Thus the decrease in GHG by using starch or sugar based ethanol will not be as high as desirable [58]. All these factors require the lignocellulose feedstocks exploitation, like agricultural and forest residues moreover as dedicated crops, with the output of ethanol. This can assistant to develop the bioconversion processes aimed towards producing the ethanol fuel, with focus on process integration. Specially, the concept that every specific unit operation needs to be optimized and developed with regards to the previous and future process steps are mentioned [55].

Employing ethanol-blended fuels rather than conventional gasoline is effective in reducing GHG and creating economic advantages by cutting health care costs. Thus, usage of 10% ethanol blends are more volatile than gasoline, which could contribute to the ozone problem, there is limited information in connection with results of various ethanol blends on fuel volatility. In particular, pure ethanol (100% ethanol) is less volatile than gasoline. Blending ETBE (ethyl tertiary butyl ether) which is produced from ethanol, with gasoline also reduce ozone problems and fuel volatility [59].

Improving ethanol product also generates marketplaces for farmers to enable them to raise farm profits. In 1995, production of ethanol has been increased from the range of 1.2-2 billion gallons annually, which could have been the improvement of about $170 million in farm profits. Producing 5 billion-gallon annually could have been raised the farm profits by $1 billion or about 2% of net farm income in 1991. When government set-aside requirements are relaxed to reduce the effects on corn prices, an increase of ethanol production from 2 to 5 billion gallons annually could reduce annual government deficiency payments by $7 million to $900 million, correspondingly. The $7 million reduction in deficiency of payments reflects a small corn price influence due to relaxed set-aside demands [59].

United States exports could increase ethanol production, as about 90% from all United States corn gluten feed (CGF) but the ethanol by product livestock feed could be exported towards the European Community. Total 1991 CGF exports exceeded 6 million tons which has a value in excess of $800 million. Ethanol manufacturing raised from 1.2 to 2 billion gallons annually, which could spur CGF exports by 2 million tons annually and improve the overall valuation of United States CGF exports by $200 million, that has been 0.5% of total United States agricultural exports in 1991 [59].

The resources allocation throughout an economy will distort by tax exemption. If markets mirrored all costs, these disturbances might make a problem to society, without any economic justification for supporting Federal assistance to ethanol. However, market failures do exist. For instance, the gasoline price does not totally reflect the actual society costs, which includes air pollution of petroleum. Moreover, the agriculture output decisions are distorted by the farm commodity programs. As such distortions exist the incentives for ethanol which may enhance the overall society welfare, depending on true costs and advantages of gasoline and its alternative options [59].

Ethanol has several disadvantages and the technology can figure out these problems. Researchers have been attempted to reduce alcoholic emissions of ethanol along with new engine designs to enhance the power output and these advantages are highly satisfying. Ethanol has the advantage of anti-knocking ability and it raised the vehicles performance and reduced the emission of pollutant. In addition, production of ethanol can enable crude oil and various fossils to fuels, which could be used in another way. Ethanol appears to have limitations however the increased rewarding qualities might help to propel their usage in hydrocarbon fueled vehicles [60].

4. Emissions characteristics

Diesel Engines emission is recognized as the main sources of promotion of pollution of the environment along with the formation of ground level ozone [61]. Enhancements of the combustion of diesel engine and the use of after-treatment technologies are predicted for reducing the emissions of the new vehicles. For operating vehicles a wide spread investigation on the usage of alternative fuels is undertaken [62].

Intensive investigation on different alcohols, mainly ethanol and methanol and combination of them with diesel fuel is used for reducing the emissions of NO_x and PM [63]. The diesel fuel and alcohols are generally employed together either in the blended mode or even in the fumigation mode [64,65], although there are less investigation being conducted on different approaches like dual fuel injection system. In comparison to the blended mode, the fumigation method is definitely seems more flexible despite extra fuel injection system is required. First it allows the quantity of alcohol to vary at the time of injection to meet the actual demand. Second, since the alcohol is not premixed while using as diesel fuel, an emulsion additive is added to ensure proper mixing of the alcohol [62].

The fumigation strategy is used during this analysis and the information is developed to compare the effect of fumigation methanol and fumigation ethanol on the diesel engine efficiency and emissions. Many scientific studies have established that NO_x and particulate can both be decreased with the ethanol and methanol fumigation. Houser et al. [66] have examined the usage of fumigation methanol for the fuel energy in the range of around 40%. Typically methanol fumigation was discovered to reduce NO_x emission, soot and also as an advantageous impact on fuel performance at high engine loads. Cheng et al. [67] and Zhang et al. [68] have described the fumigation methanol effect on different emissions of exhaust gases and PM [62].

It can be an overpowering debate (up to 87.7%) that the usage of biodiesel rather than diesel causes the reduction of PM emissions [69–112]. Their outcomes confirmed that by using biodiesel the PM and NO_x emissions decrease and also improve the HC and CO emissions. However, Hayes et al. [113] have investigated the influence of fumigation of ethanol on gaseous emissions plus the in-cylinder pressure, generation. Additionally, they have noticed many times the increase of emission of CO and HC from biodiesel burning in comparison to diesel fuel except lower emission of NO. The rate of pressure increase and peak pressure was reported significantly higher for the fumigated ethanol. Similar outcome was acquired by Jiang et al. [114]. They examined the ethanol fumigation result on the performance and emission of a 4-cylinder, TU diesel engine. Leahey et al. [115] also recommended that fumigation of ethanol can be quite a viable technique of offsetting petroleum diesel although it decreases diesel soot emissions and avoids lubricity problems as obtained while ethanol-diesel blended fuel was used. Surawski et al. [65] concentrated their focus on PM emissions, and the toxicity, from an ethanol fumigated CI engine [62]. The 65.2% of the researcher believe that NO_x emission is increased by the use of pure biodiesel [69,72,76,79,80,83,85,86,93,95–98,110–112,116–127]. NO_x emissions increase by 15% for B100 at enhanced load condition due to the product higher gas temperature in combustion chamber with 12% oxygen content in product gas [110].

There are a few research targeted the comparison of fumigated methanol and ethanol effect on the emission of diesel engine [114,128,129]. In the previous investigation of fuels, the particle size distribution was not measured [62].

On the other hand, due to the influence of particle size on the health [130], the size distribution and concentration of PM emissions from various fuels are currently widely examined [65,67,68,131,132]. Some research on comparison of the particle number concentration and size distribution from the CI engine operated by using ethanol and methanol fumigated fuels and the Euro V diesel fuel as the base line fuel. In addition to the particle number distributions, HC, CO, PM and NO_x emissions are compared and examined [62]. Many researches (84.4%) obtained a benefit by replacing diesel oil by pure biodiesel and observed reduced emission of CO [69–71,75,76,78,79,81,83,86,90–92,95,98,107–109,116,118,124,125,133–136].

The leaning influence of ethanol to raise the air–fuel equivalence ratio (γ) is higher and produces the burning nearer to the stoichiometric ratio. Consequently, the higher combustion can be carried out and higher torque output can be acquired [40]. However, some studies [71,76,81,90,92,100,105,106,118] have noticed the less reduction. Puhan et al. [105] achieved the reduction of CO around 30% whereas Utlu and Koçak obtained 17.3% [71]. At the same time, Wu et al. [106] observed that 5 types of bio-diesels have previously reduced the emission of CO by the range of 4–16%. However, several researches described that there is no reasonable difference in CO emissions between diesel and biodiesel [82,85]. This can be mainly related to low emissions [137].

Six different car engine emissions from 1990 to 1992 were tested for different ethanol–gasoline blends of volumetric ratio range from 10% to 40%. The linear emission variations were discovered with respect to ethanol percentage. The highest percentage of ethanol (42%) has reduced the emission range of the CO and HC about 50% and 30%, respectively, along with the fuel consumption improvement of around 15% [138].

Gasoline blends containing oxygen on emissions were tested on six cars. The studies were carried out on framework dynamometer by using ECE cruise cycle. Within the cycle 10% MTBE, 15% MTBE and 5.2% ethanol were utilized as fuel and the CO emission 15–30%, HC emission 10–20% and NO_x emissions 1.3–1.7% reduction were observed [139]. It was obvious that 89.5%, HC emissions are reduced by pure biodiesel in comparison to diesel fuel [70,72,76,78–82,85,87,97,98,119,124,135,136]. Wu et al. [106] mentioned that these five different types of biodiesel have reduced HC emission by 45–67% on the average in comparison to diesel fuel. Some scientists [70,72,78,105,107,140,141] have observed the similar noticeable reduction.

The emissions of HC and CO decreased by 24.3% and 46.5%, respectively, and CO_2 increased about 7.5%. The most effective performance and emissions were achieved for 80% unleaded gasoline and 20% ethanol blend, respectively. Gasoline and ethanol blends and the effects of compression ratio on engine performance were investigated by some researchers [142]. Within the scope of investigation 10%, 20% and 30% ethanol–gasoline blends were used as fuel. The best compression ratio for obtaining the obtained highest indicated power was settled for each blend. At 10%, 20% and 30% ethanol–gasoline blends, the ideal compression ratios obtained were 8, 10 and 12, respectively [40]. Some researchers have studied CO_2 emission from biodiesel and stated that it could be as high as 23% [143]. Some authors [70,71,83,96,126] have reported that, the biodiesel generates less CO_2 emission in comparison to diesel oil in a complete combustion from lower carbon to hydrogen ratio fuel.

Table 4
Bio-fuel statistics effects on engine emission and performances [137].

Variable parameters	Total number of references	Increase		Similar		Decrease	
		Number	(%)	Number	(%)	Number	(%)
Power performance	27	2	7.4	6	22.2	19	70.4
Economy performance	62	54	87.1	2	3.2	6	9.7
PM emission	73	7	9.6	2	2.7	64	87.7
NO_x emission	69	45	65.2	4	5.8	20	29.0
CO emission	66	7	10.6	2	3.0	57	84.4
HC emission	57	3	5.3	3	5.3	51	89.5
CO_2 emission	13	6	46.2	2	15.4	5	38.5
Aromatic compound	13	–	–	2	15.4	11	84.6
Carbonyl compound	10	8	80.0	–	–	2	20.0

5. Engine performance

Biodiesel is an engine fuel, which is developed by chemically reacting alcohol and acids as stated before and blended with diesel oil. Other more important points to keep in mind are engine power and economic performance. Engine performance is reflected in power output, fuel consumption, cost involvement in unit power output, etc.

5.1. Engine power

Pure biodiesel effect on engine torque and power is presented in Table 4. The 70.4% of researchers have agreed that engine power can be dropped with biodiesel as fuel due to the LHV of biodiesel [69–72,74,75,77,79,117,118,133,134,144–146]. However, the outcomes provided some fluctuation in the result [137]. Many researchers [69–72,74,75,77,79,117,118,133,134,144–146] have recognized that the power loss was less than the expected due to power recovery. The average torque and power values of WFOME were reduced by 4.3% and 4.5%, respectively due to higher viscosity and density in comparison to diesel fuel [71]. Utlu at al. [71] have also observed that the lower heating value diminishes the torque about 8.8%. The break torque of the test engine was studied by Hansen et al. [49,117] who considered variation of the results of viscosity, density heating value of the fuel. They observed the break torque loss 9.1% when B100 biodiesel was used as fuel instead of D2 diesel at 1900 rpm. Murillo et al. [134] studied the performance of biodiesel in a 3-cylinder, N/A, submarine diesel engine at full load. They have noticed the power decrease of 7.14% for biodiesel in comparison to diesel. They have also recognized that the heating loss value of biodiesel was 13.5% in comparison to diesel fuel [137].

A similar range from the decreased heating value and also power loss was described in a few research works [146,147]. The performance of biodiesel from cotton seeds was examined by a few researchers. They have noticed power and torque reduction of 3–6% by using pure biodiesel instead of diesel oil. They have also identified that the biodiesel heating value was 5% less than diesel fuel. However, the researchers made responsible the atomization behavior of the fuel for lack of power rather than loss of heating value [137].

Biomass, when exposed to heat in the absence of oxygen (i.e., pyrolysis), it converts into liquid, solid char and gas product. The liquid product, known as bio-oil or pyrolysis oil, is usually brown, crimson, or black in color that has a density of concerning 1.2 kg/L. Bio-oil has water content of usually 14–33% weight, that could not be simply removed by typical ways (e.g., distillation). HHV of bio-oil range is frequently 15–22 MJ/kg which is certainly below that for typical fuel oil (43–46 MJ/kg), mainly attributable to the existence of oxygenated compounds in bio-oil [148]. For convenient use of biomass since the middle of 20th century, the researchers have been started to convert it into petroleum-like liquids [9].

As an example, Berl processed biomass with alkaline water at 500 K to generate a viscous liquid, which contains 75% heating value and 60% carbon material [149]. The biocrude contains 10–20% weight oxygen and 30–36 MJ/kg heating value compared to $<1\%$ weight oxygen and 42–46 MJ/kg of heating value in petroleum [150]. The high oxygen content imparts lower energy content, lower volatility, poor thermal stability, higher corrosiveness and tendency to polymerize after sometimes [151]. In comparison to bio-oil from pyrolysis, the biocrudes are constructed from hydrothermal liquefaction having minimum moisture content and higher heating value and it also needs better capital prices and longer residence time [9].

It has been noted that there seemed to be no essential difference in engine power between pure diesel and biodiesel [80–84,135,152]. As an example, Lin et al. [80] have demonstrated the highest and lowest variations in engine torque and power at full load with 8 types of vegetable oil methyl ester (VOME) fuels and petroleum diesel. Later Qi et al. [81] have mentioned about the trend, and said the engine delivers power on the basis of density of biodiesel and the volume, which is higher than the diesel amount of needs to produce the same heating value [137].

Researchers have found an unexpected improvement in torque or power by using pure biodiesel engine [85,119]. Song and Zhang [85] have noticed that the torque and brake power of engine have increased with the increase in biodiesel blends percentage, thus the biodiesel consumption have increased. The higher oxygen content and injection timing will cause the advancement of a shorter ignition delay time. However, it is incredible that the improved power of the pure biodiesel can achieve 70% of the diesel fuel, as the outcomes may increase more with the viscous and more dense fuel mass from biodiesel and its blends [137].

5.2. Economic performance

Many scientific studies (up to 87.1%, Table 4) [70,71,73,75,78–80,87,90–96,102,103,116–118,120,122,124,125,127,133,134,136,145,146,153,154] have agreed that an engine runs with the higher fuel consumption due to LHV of the fuel. Most of the study [70,79,90,102,116,145,153,155,156] have reported that the less amount of the diesel fuel consumption against biodiesel is due to the LHV of the biodiesel. Armas et al. [154] have noticed that the brake specific fuel consumption of B100 biodiesel (having LHV, about 12.9% less than that of BP15) had increased around 12% in comparison to the BP15 while running a 2.5 L, TU and DI, common-rail diesel engine at 64 N m and 2400 rpm. Hasimoglu et al. [153] have achieved the upper BSFC 13% for diesel but 13.8% for biodiesel on a 4-cylinder, DI and TU engine. Lin et al. [80] have examined the BSFC of 8 different types of vegetable oil methyl ester in a 1-cylinder, 4-stroke, DI, WC engine. They found the higher range of BSFC from 9.45% to 14.65% for biodiesel compared to diesel fuel, which refers the same result obtained in the case of LHV range from 12.9% to 16% obtained from these vegetable oil methyl esters [137].

Many researchers [75,95,103,118,127,133] have demonstrated that the increase of biodiesel fuel consumption ratio is more than LHV ratio. Lujan et al. [95] have noted that the variation in fuel requirement was 18.5% in mass between the pure biodiesel and the diesel. They have also noticed that the variation had decreased to 13.5% in volume due to high density of biodiesel. Labeckas and Slavinskas [127,133] have informed that the pure biodiesel BSFC (LHV is lower than 12.5%) was increased by 18.7% at 1800 rpm and

Table 5
Bio-fuels classification on different generations of technologies [9].

Generation	Feedstocks	Examples
First	Sugar, starch, vegetable oils or animal fats	Bioalcohols, vegetable oil, biodiesel, biosyngas, biogas
Second	Non food crops, wheat straw, corn, wood, solid waste, energy crop	Bioalcohols, bio-oil, DMF, biohydrogen, bio-Fischer-Tropsch diesel
Third	Algae	Vegetable oil, biodiesel
Forth	Vegetable oil, biodiesel	Biogasoline

23.2% at 2200 rpm. They have observed [133] that the raised BSFC was higher than 18% for B100 biodiesel in comparison to diesel alone [88,91,146] however the decrease of heating value was concerned about 8% for the biodiesel [137]. Gumus and Kasifoglu [88] have demonstrated that the BSFC for B100 was 4.8% higher than that of diesel fuel due to a higher viscosity and LHV of about 7.4% [137].

It has been reported by some authors [72,74,76,85,89,157] that fuel consumption of biodiesel was decreased compared to diesel. Ulusoy et al. [76] have examined in a 4-cylinder, 4-stroke 46 kW diesel engine and informed that the frying oil biodiesel fuel consumption was 2.43% decreased compared to diesel fuel [137]. Some researchers [104,158] have observed no noticeable difference between diesel and pure biodiesel. Dorado et al. [158] have investigated waste olive oil biodiesel in a 3-cylinder 2.5 L engine with different testing models, and observed no significant variations in BSFC in comparison to diesel. It had been informed by Sahoo et al. [104] that BSEC is slightly higher for B100 at lower loads and remains same at higher loads [137].

6. Additives

A number of properties of fuel can be important for the precise operation of diesel engine. Addition of ethanol to diesel fuel has influenced certain important properties specifically energy content, cetane number, blend viscosity, stability and lubricity. Materials corrosiveness or compatibility can also be the critical factor, which is needed to be considered. Properties affecting the safety need to be foremost in any fuel analysis. These contain flammability and flashpoint. Fuel biodegradability has generated an important problem with respect to pollution of water resource [49].

6.1. Bio-fuel classification

Bio-fuel shares of energy companies are increasing while using the fuel cell systems for supplying renewable energy. The strategy of renewable energy improvement embodies the thought of the inter-linkage and also the balance between social, environmental and economic factors. European Countries are introducing policies on different bio-fuels marketing [159,160]. The marginal product is dependent on the bio-fuels policy stances. Bio-fuel costs must not be used as an anti inflationary device. The developed data of a required share of the bio-fuels from 2009 informs that the lowest blending shares [161] are to be considered for recommending bio-fuels.

Bio-fuels might be categorized into the four groups depending on the production technologies. Categorization of bio-fuels is dependent on the technology of production as presented in Table 5. The first-generation of bio-fuels seems to be not sustainable as a result of potential focus on food production commodities. Second generation of the bio-fuels got a chance to develop the advantages of eco-friendly fuels as produced in addition to hydrothermal and pyrolysis liquefaction. Fischer-Tropsch attached an alternative catalytic procedure to produce additional advanced material and molecules, on that another sustainable society will probably be dependent [162,163].

6.2. Blend stability

There are two factors influence the solubility of ethanol in diesel oil, water content and temperature of the blend. Dry ethanol blends readily with diesel fuel at the warm ambient temperatures. However, both fuels are separated below about 10 °C, a temperature limit that is easily exceeded in many aspects of the world for the large portion of the year. Protection against this separation could be achieved in two ways: with the addition of an emulsifier that suspends small droplets of ethanol inside the diesel oil or by adding a co-solvent to provide a bridging agent through molecular compatibility and bonding to generate a homogeneous blend [164]. Heating and blending steps are required in emulsification to create the final blend, whereas co-solvents allow fuels to become “splash-blended”, therefore simplifying the processing of blend [49].

Both co-solvents and emulsifiers are evaluated from diesel fuel and ethanol. The micro-emulsions of aqueous ethanol (5% water) and diesel fuel can be prepared by employing a commercial surfactant, which has been analyzed by Moses et al. [165]. They noted that the blends spontaneously formed by a little string only. Additionally, they have demonstrated that the dispersion sizes were less than one quarter of the wavelength of light and were considered to be infinitely stable, like thermodynamically stable without any separation even after several months [49].

Approximately 2% surfactant was essential for each 5% aqueous ethanols added to diesel oil. Boruff et al. [166] produced formulations for two micro-emulsion surfactants of one ionic and the other with detergentless. These blend surfactants with diesel fuel and aqueous ethanol at temperatures as low as 15.5 °C were transparent and stable. The researchers from Sweden [49] have tested a 15% aqueous ethanol blend (5% water) with diesel fuel that contains DALCO, an emulsifying agent developed in Australia. Letcher [164], Meiring et al. [167] and Letcher [168] have recognized as effective co-solvents tetrahydrofuran available at low price from agricultural waste products and ethyl acetate that could be produced at low costs from ethanol. Diagrams of Ternary liquid–liquid phase diagrams are demonstrating the relative results of moisture content and temperature on blend stability along with the requirement of co-solvent for improving moisture and temperature to keep up like single phase liquid as demonstrated in Figs. 1 and 2. Letcher [168] figured out that the quantity of ethyl acetate added to ethanol is ensuring complete miscibility at constant ratio 1:2 at 0 °C[49].

6.3. Lubricity and viscosity of fuel

Fuel lubricity and viscosity are playing an essential role in the lubrication of fuel injection systems, significantly in those rotary distributor injection pumps incorporator and they are fully dependent on the fuel for lubrication among the pumping mechanism at high pressure. The high-pressure pump in the common rail accumulator of fuel-injection system, which provides fuel for the rail and is

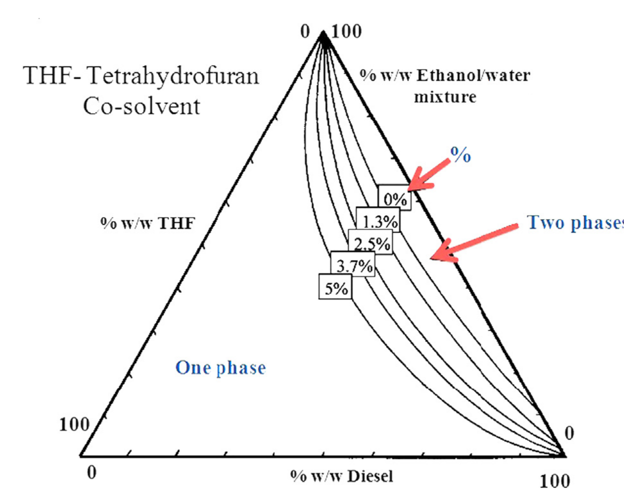

Fig. 1. Liquid–liquid ternary phase diagram for diesel fuel, tetrahydrofuran and ethanol or ethanol water mixtures with the temperature controlled at 0 °C [164].

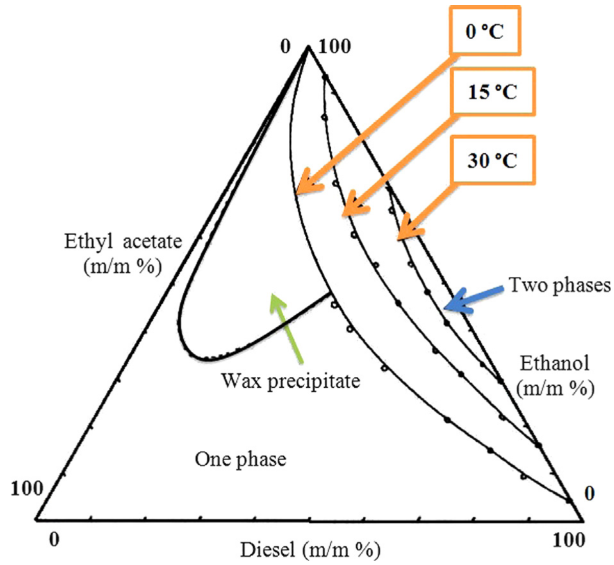

Fig. 2. Liquid–liquid ternary phase diagram for diesel fuel, ethyl acetate and dry ethanol mixtures [168].

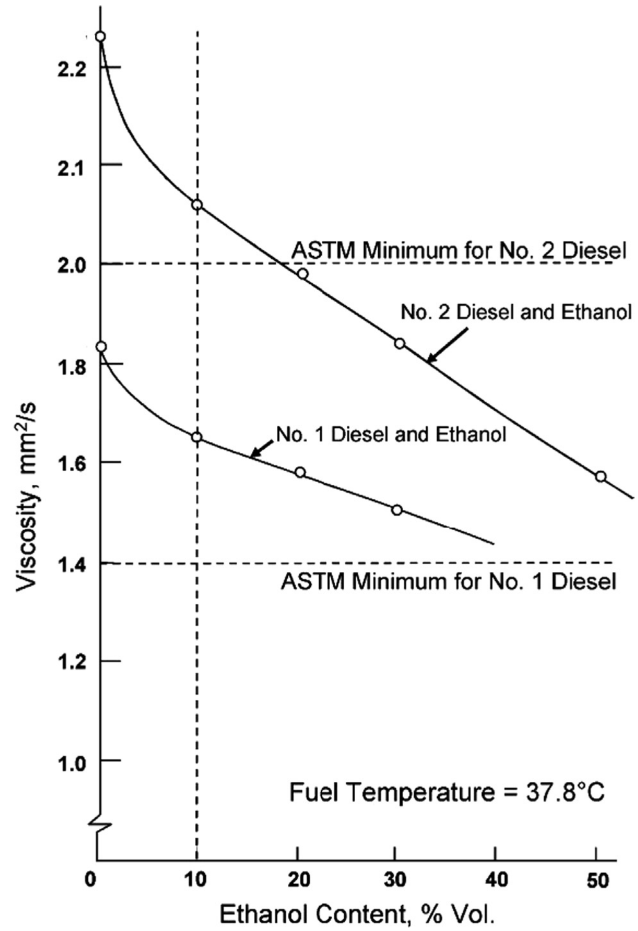

Fig. 3. Effect of ethanol content on fuel viscosity [169].

determined by the fuel for lubrication. There is less reliance on the fuel for lubrication in pumps in-line and unit injectors. However, there are some requirements for some metal interfaces lubrication by the fuel such as between barrel and plunger. Specifically lubrication of injector lubrication can also be affected, that is at the needle guide-nozzle body interface [49].

The result of low viscosity fuels is great in pumping, which reduces leakage of injector, maximizes level of fuel delivery and ultimate power output. Hot restart problems also could be experienced as insufficient fuel is injected at cranking speed when fuel leakage in the high-pressure pump is increased due to the reduced viscosity of the hot fuel [49].

Wrage and Goering [169] presented the variation of kinematic viscosity with percentage of ethanol (Fig. 3). It is observed that a blend of 18.5% dry ethanol (1.1 mm^2/s viscosity) with No. 2 (Fig. 3) diesel (2.46 mm^2/s viscosity) could be equal to the fuel grade of ASTM having minimum viscosity of 2.0 mm^2/s at 37.8 °C, which could be well above the lowest for No. 1 (Fig. 3) diesel as shown in Fig. 3. Speidel and Ahmed [170] have demonstrated that the viscosity of 2.25 mm^2/s for any blend contains 15% dry ethanol, 5% PEC additive and 80% diesel. It might be mentioned that the viscosity of the final mixture is dependent upon the viscosity of the diesel fuel. Blending ethanol with a diesel fuel of lowest viscosity could produce a standard viscosity less than the minimum in ASTM [49].

6.4. Materials compatibility

Following capability of materials in 1980s ethanol was used in gasoline engines and investigations were launched for compatibility research, such as blending of ethanol and diesel fuel for using in diesel engines and observed that it effects especially in the fuel injection system. The ethanol quality has been influenced strongly by the effect of corrosion from it [171]. In addressing the ethanol corrosion problems relevant to gasoline blends, Brink et al. [172] have studied the ethanol corrosion and divided it into three classes: wet corrosion, dry corrosion and general corrosion. Ionic impurities were identified as the cause of general corrosion and acetic acid and chloride ions are the most contributors. The ethanol molecule and its polarity are considered responsible for dry corrosion. de la Harpe [173] has studied dry corrosion on metals by ethanol and found that aluminum and magnesium were more prone to chemical attack by dry ethanol [49]. The causes of wet corrosion are azeotropic water that oxidizes most metals [172].

Freshly formulated blends of dry ethanol having natural pH would be expected to have relatively little corrosive impact. Ethanol when absorbs moisture it becomes more corrosive and the impact is observed while passing through the fuel injection system [173]. Moreover, by substitution of fuel injection system in several months, for example in a combine harvester engine ethanol fuel could be used. It may corrode elements of the pump inside. Corrosion inhibitors have been incorporated in blends of ethanol and diesel fuel [173].

Non-metallic parts have also been attacked by ethanol such as elastomeric parts like O-rings and seals inside the fuel injection system. These seals usually become stiffen and swell. Resin-bonded or resin-sealed parts are prone to swelling and affected [49].

7. Incentives for bio-fuel production

Of the total global fuel energy demand about 67% is supported by fossil fuel and 33% is furnished by all the available renewable energy sources, like hydroelectric, wind, solar, etc., targeting mainly the power generation market [174,175]. Current statistics says that the total reserves of fossil fuels are 260 billion cubic feet of natural gas and about 85 million barrels of oil daily and the amount of natural gas available for 64 years and oil for 40 years [176]. Microorganisms of lipid-accumulating in nature such as microalgae, yeast and cyanobacteria could be used for biodiesel manufacturing. Solar energy as alternative source of power is being utilized by different means. Thus, energy from solar resource

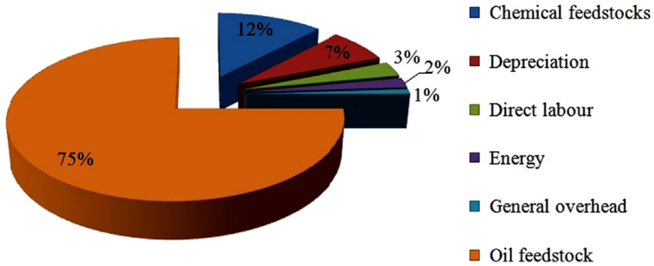

Fig. 4. General cost breakdown for production of bio-fuel [186].

is used by plants for nourishment and to grow seeds to produce oil for edible and energy source. Finally, it provides an energy change phenomena from solar to dense chemical form as biodiesel of all kinds [176].

In global positioning location 30–45° latitude the corn grows. North America (and, of course, a corresponding arc in the southern hemisphere) covers almost the whole region remaining under arc and 240 W m^{-2} is the average power density of sunlight in these regions [177]. Adverse effect of weather is not being considered here and therefore it must be regarded as a maximum average. The plants collect light energy from the wavelength ranging between 400 and 700 nm of the incident sunlight representing 43% of the total solar energy arriving on the surface of earth [177,178]. Thus, the maximum useful power density of sunlight useful for photosynthesis is

$$(240\ \mathrm{W\ m^{-2}}) * 0.43 = 103\ \mathrm{W\ m^{-2}} \qquad (1)$$

To enable cross-fertilization corn needs to be grown in rows and thus it does not cover 100% of the available land. At best, about 80% land of the planet can be used for farming. Thus the growing plants can see the maximum solar power as shown in the following equation:

$$(103\ \mathrm{W\ m^{-2}}) * 0.80 = 82\ \mathrm{W\ m^{-2}} \qquad (2)$$

The concept of using vegetable oil as fuel dates back to 1895 [179]. Some of the disadvantages of using biodiesel are listed below:

1. Slight degradation in fuel economy on the basis of energy (about 10% for pure biodiesel).
2. In cold weather the density is more than diesel fuel, but may need to use blends in different conditions of sub-freezing.
3. More expensive than diesel fuel due to less vegetable oil production [180].

Huntley and Redalje [179] reported that the average biomass energy production is 763 GJ/ha/year at Hawaii. The 422 GJ/ha/year is the average oil yield estimated by the researchers, which is roughly 0.6% of incident solar energy, considering over 1200 gal of biodiesel per acre-year, representing far better than conventional oil bearing crops [176].

The total global energy demand is 13 TW/year (in 2000 predicted to rise to 46 TW in 2100), whereas the total incident solar energy is 178,000 TW/year, which is 13,500 times the total global energy demand. These information convince us to use solar energy systems and it is advantageous even in countries having poor irradiation [181].

The algae production price ranges $ 6.5–8 per gallon. By economic modeling it reveals that algae cost is competitive to corn and sugar-cane-based bio-ethanol prices [182]. Schenk et al. [174] stated that the fuel extracted from algae costs $ 39–69 per barrel as estimated by Schenk et al. [174] whereas the cost evaluated by others around $84 per barrel [174,176,183]. Solar energy can help to recover the energy needed to produce biodiesel [184]. Making use of this resource and microalgae may have a profound impact on food and energy security, global warming and human health [183].

Table 6
Current potential feedstocks for bio-fuel production worldwide [186].

Country	Feedstock
USA	Soybeans/waste oil/peanut
Canada	Rapeseed/animal fat/soybeans/yellow grease and tallow/mustard/flax
Mexico	Animal fat/waste oil
Germany	Rapeseed
Italy	Rapeseed/sunflower
France	Rapeseed/sunflower
Spain	Linseed oil/sunflower Greece cottonseed
UK	Rapeseed/waste cooking oil
Sweden	Rapeseed
Ireland	Frying oil/animal fats
India	Jatropha/Pongamia pinnata (karanja)/soybean/rapeseed/sunflower/peanut
Malaysia	Palm oil
Indonesia	Palm oil/jatropha/coconut
Singapore	Palm oil
Philippines	Coconut/jatropha
Thailand	Palm/jatropha/coconut
China	Jatropha/waste cooking oil/rapeseed
Brazil	Soybeans/palm oil/castor/cotton oil
Argentina	Soybeans
Japan	Waste cooking oil
New Zealand	Waste cooking oil/tallow

There are more than 350 oil-bearing crops recognized worldwide as potential sources for bio-fuel production. The broad range of existing feedstocks for bio-fuel production represents one of the most important advantages of bio-fuel [185]. According to some researches [186–188], feedstock acquisition currently accounts for over 75% of bio-fuel production expenses as depicted in Fig. 4.

In general, bio-fuel feed- stocks can be divided into four main categories as below:

1. Edible vegetable oil: canola, soybean, peanut, sunflower, palm and coconut oil.
2. Non-edible vegetable oil: *Jatropha curcas*, *Calophyllum inophyllum*, *Moringa oleifera* and *Croton megalocarpus*.
3. Waste or recycled oil.
4. Animal fats: chicken fat, pork lard, beef tallow and poultry fat.

Table 6 shows primary bio-fuel feedstock for some selected countries around the world. The initial evaluation of the physical and chemical properties of edible and non-edible feedstocks is very important to assess their viability for future bio-fuel production.

7.1. Food price evolution

Simulated value of actual demand for food crops as bio-fuel feedstock up to 2007 and bio-fuel growth in 1990–2007 are compared. It is observed that to meet the growing demand of bio-ethanol and bio-fuel the price of crop grain grown up from 2000 to 2007. The weighted average grain price is grown up to 30% compared to previous rate of increase due to the demand of bio-fuels and bio-ethanol during the stipulated time. Considering price impact on maize, the increased bio-fuel demand is estimated to account for 39% of the price hike. On the other hand increase in price of rice and wheat about 21% and 22%, respectively refers to increasing the bio-fuel demands (Fig. 5) [189].

7.2. The freezing impact on bio-fuel production

Rosegrant [189] has foreseen that with the cessation of bio-fuel production in 2007, the price for all crops in all countries used as feedstock will remain unhindered whereas the projected maize could have been declined by 6% within 2010 and 14% by 2015. Smaller price reductions are also expected for oil crops, cassava, wheat, and sugar (Fig. 6) [189].

7.3. The elimination impacts on bio-fuel production

Considering no bio-fuel demands from food crops (or a global moratorium on crop-based bio-fuel production were imposed) after 2007, prices of key food crops would have dropped more significantly in order of 20% for maize, 14% for cassava, 11% for sugar, and 8% for wheat by 2010 (Fig. 7) [189].

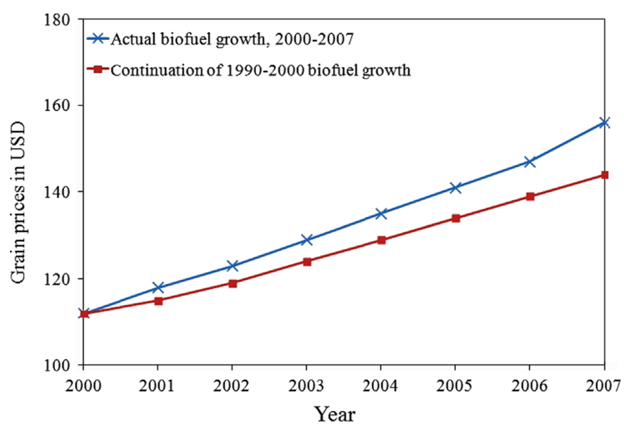

Fig. 5. Simulated real grain prices from 2000 to 2007 (USD$/metric ton) [189].

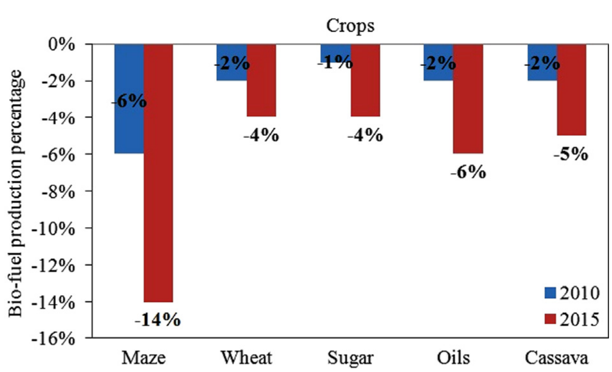

Fig. 6. Change in selected crop prices if bio-fuel demand for all crops was fixed at 2007 levels [189].

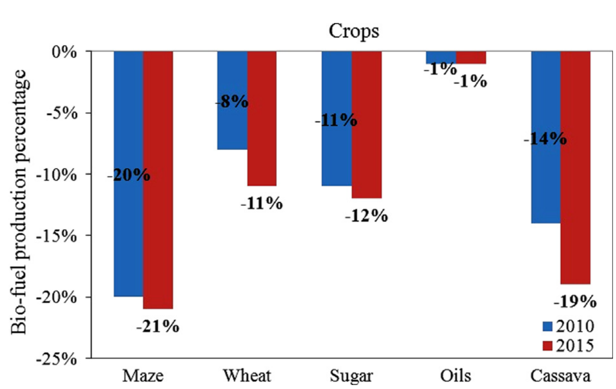

Fig. 7. Change in selected crop prices if bio-fuel demand is eliminated after 2007 [189].

8. Impact on environmental from bio-fuel

The basic idea of the life cycle assessment, which is sometimes also called cradle-to-grave analysis, is to reveal all environmental impacts a certain product causes throughout its whole lifetime. Hence, the life cycle describes all processes from raw material extraction to produce the product to its final disposal [190]. The environmental aspects of ethanol over gasoline are an eco-friendly, renewable and totally sustainable resource and less polluting fuel. Probably, the most necessary factor could be CO_2 emission by ethanol combustion, which has recently been fixed by growing plants, thus this GHG could not make any net contribution to climatic change and global warming, which is a crucial fact for the United States and they are responsible for 23% of global GHG pollutants. However, requirement of energy is necessary for all the facets of the methods, such as the planting and cropping, production and fertilizers distribution, production of the ethanol, and distilleries manufacturing; most of this energy derives from non-renewable fuels. In 1988, ethanol production in Brazil was 19% of the total liquid fuel consumption [191]. The power generation from ethanol is twice energy input, while bagasse is used as fuel [192]. The requirement of fossil fuels may provide a negative energy balance, if maize can be associated in cost of distribution and production [193]. However, this can be useful for environmental protection if it can be replaced by use of some fossil fuel in power areas [194]. Many of the earlier analyses on ethanol fuel production concerned it as higher level of polluting and low performance fuel [191].

Since 1990, overall production range of ethanol in Brazil has increased about 4% annually and consequently 13% of total national energy demands are provided by ethanol. Concomitantly, they have reduced price by 3% per year considering the PROALCOOL, from a new sugar-cane variety blend, which has improved the manufacturing process (distillation, fermentation and extraction) and the cultivation methods. During the past years, the same achievement has been considered in the United States, which is mainly caused by utilizing modern technologies at fermentation plants and due to this the ethanol production cost has been reduced by two-thirds [191,195].

Enhancements in all areas of the production process have been sustained and successful, so modern improvements are always being discovered, although a lot of remaining items to be demonstrated in the industrial setting. Mainly, Bagasse can be used for energy supply and generation of steam for heating, crushing, juice concentrating and ethanol distillation. In the dry season of Brazil the requirement of the electricity is high and the supply of hydroelectric power at the lowest level. The 20% of the surplus bagasee is helping the cogeneration of electricity production and can be offered to the electricity companies. Additionally, hydrolyzed bagasse could be employed in the paper industry and animal feed that is certainly being investigated to build a new product [196]. Originally, maize and sugar-cane stillage was disposed of in water resources like river, pond, etc., and it became a substantial pollutant. Additionally, it can be employed in the controlled environment of methane (biogas) output or as land fertilizer. Traditionally, they burned the leaves and tops, before harvesting sugar-cane [191]. However, plants can be harvested completely by modern technology and the tops could be burned in the high-efficiency distilleries or boilers, which can be used for gasification [197] and could increase the total energy return up to 40% [191].

One critical environmental issue is the degradation of soil which causes erosion and appears due to intensive agriculture by the range 10–30 times more rapid in comparison to undisturbed soil [198]. Currently, there are a few researchers attempting to defuse this challenge. A large amount of input nitrogen as fertilizer is added to raise production of the agricultural crops

Table 7
Impact of engine exhaust on human health [186].

Exhaust emissions	Impact on health
PM	Lung cancer and cardiopulmonary deaths
NO_x	Irritate the lungs and cause edema, bronchitis and pneumonia; and result in increased sensitivity to dust and pollen in asthmatics
CO	Its affects fetal growth in pregnant women and tissue development of young children. It has a synergistic action with other pollutants to promote morbidity in people with respiratory or circulatory problems
HC	Eye irritation, coughing and sneezing, drowsiness and symptoms akin to drunkenness. Some hydrocarbons have a close affinity for diesel particulates and may contribute to lung disease
PAHs	Eye and nose irritation, coughing, nausea and shortness of breath
Formaldehyde	Eye and nose irritation, coughing, nausea and shortness of breath

Table 8
Factors affecting the engine emissions [186].

Factors	References for NO_x	References for CO	References for PM	References for HC
Biodiesel feedstocks	[80,108,152,206]	[96,106,206,207]	[207–209]	[106,108]
Contents of Biodiesel	[86,88,108,121,124,134]	[86,133,134,210]	[69,74,75,86,99,211]	[99,157,209]
Higher cetane number	[72,209,212–214]	–	[85,211,215]	[216]
Advance injection timing	[96,108,209]	[118,123,154]	[70,212]	[70,99,154]
Higher oxygen contents	[127]	[92,120,124]	[217]	[105]
Engine load	[78,88,93,97,121,134,212]	[88,107,120,122]	[73,78,110,218]	[27,32,44]
Engine speed	[108,219]	[81,108,126]	[85,107]	–

which leads to crucial energy charges for the transport, synthesis and fertilizer usage. In addition pollution could be experienced due to excess nitrogen run-off and also nitrification of water-courses [191].

The farmers who monitor the effects of nitrogen content can limit the nitrogen inputs to reduce the usage substantially. The endophytic bacteria which is responsible for nitrogen-fixing have been found in both the sugar-cane and maize [191,199]. It is required to confirm directly, the roles of biological nitrogen-fixing. It has become a fact that around 60% of the required nitrogen is supplied endogenously in plant when sugar-cane is grown in a low-nitrogen soil, [196]. Generally, ethanol fuel produces less GHG pollutants in comparison to gasoline. Substituting gasoline by ethanol and also by the usage of ethanol blends, the large amount of gasoline pollutants could be decreased [200]. Due to a low vapor pressure of ethanol the combustion can make acetaldehyde [201] along with released VOCs [191].

Due to the clean air Act Amendments at United States [202] the oxygenated additives in gasoline like ETBE, MTBE or ethanol, should be added to reduce the GHG and VOCs at least about 2% by weight of oxygen. Reformulated Federal Gasoline (RFG) Program could provide guidance to control generation, which may control the volatility content of gasoline through the entire hot season in specific areas. The Federal Oxygenated Fuels Program needed gasoline to contain 2.7% oxygen in several designated risky aspects of CO pollution in cold season. The RFG program has become successful in reducing the GHG of gasoline either indirectly or directly by the amount less than anticipated [203].

8.1. *Impact of engine emissions on environment and Human health*

The emissions which are produced due to combustion of petroleum derived fuel have an adverse effect on environment and human health [185]. It is reported by the unite nation intergovernmental panel that global warming is increasing due to the green house gas emission including methane, nitrogen oxides and carbon dioxides. Liaquat et al. [204] reported that if the average global temperature is increased by more than 2 °C, many people about hundreds of millions of people will lose their lives. Carbon monoxide (CO), hydrocarbon (HC) and formaldehyde (HCHO), Oxides of nitrogen (NO_x), particulate matter (PM) and organic gases other than methane (Non-Methane Organic Gases, i.e., NMOG) which are emitted from internal combustion engine has been identified as harmful to the human health and environment degradation. Table 7 shows the impact of exhaust emissions on human health.

8.2. *Factors affecting engine emission*

Both the regulated and unregulated emissions are affected by the following factors; bio-fuel feedstocks (sources); contents of bio-fuel, cetane number, advance injection timing and combustion, oxygen contents, engine load, engine speed, density and viscosity [186,205]. A summary of various reports regarding the factors which have effect on engine emissions such as NO_x, HC, PM and CO has been presented in Table 8.

9. Summary

Bio-fuel is produced from renewable sources and it can play increasingly a major role in support of meeting energy demand in transportation systems. There have been inconsistent trends for the performances of bio-fuel engine and different ranges of gases emission during varied biodiesel blends and operating conditions or driving cycles. Pressures on international grain marketing have influenced the prices during the past years. The efficiency of bio-fuel production has steadily increased with some valuable co-products, but still the fossil fuels are available at a comparatively low price. Now only tax credits make bio-fuel commercially viable because fossil oil is all the time available at a low price. The original motivation for bio-fuel production needs to become more independent of oil imports as the emphasis is on its use as an oxygenated gasoline additive. Due to the retarded grain growth and rapid growing demand for grains the price of biodiesel can be easily reversed. The global food economy is facing demand for food, feed, and fuel and also the future challenges of increasing land-use pressures and climatic changes. The agricultural productivity will have to grow significantly faster in the future than it had been in the recent past years. Lack of easy access to food will influence food prices, such as possible long-term illness, irreversible consequences for health, productivity, and well-being particularly if higher prices result in reduced food consumption by infants

and preschool children. If the current bio-fuel expansion continues, calorie availability in developing countries is expected to grow slowly which will lead to higher number of malnourished children, even though the agricultural income would also accelerate. Finally, a comparison on use of fossil and bio-fuel is provided to meet all the relevant challenge.

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